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(71) Applicant(s)
The Welding Institute

(Incorporated in the United Kingdom)

Abington Hall, Abington, Cambridge, CB1 6AL, United Kingdom

(72) Inventor(s)
David John Abson
Philip Leslie Threadgill
Wayne Morris Thomas

(74) Agent and/or Address for Service
Gill Jennings & Every
Broadgate House, 7 Eldon Street, LONDON, EC2M 7LH, United Kingdom

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GB 2222376 A GB 1472002 A

(58) Field of Search
UK CL (Edition L) B3R, B5K
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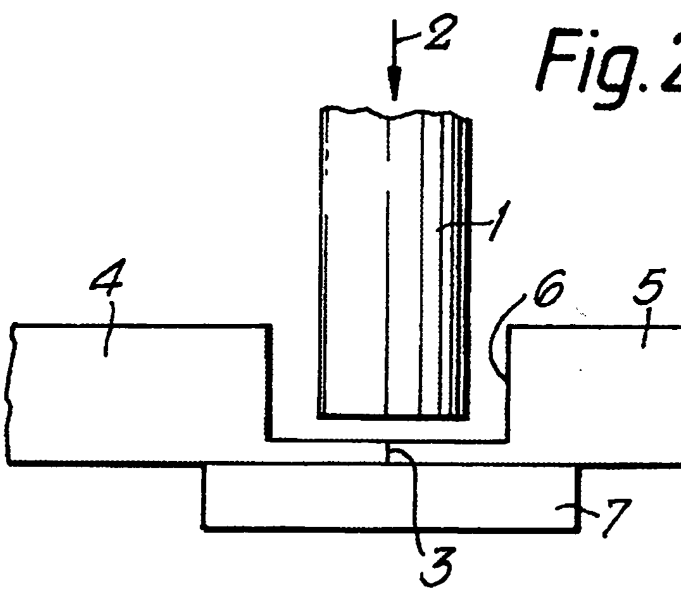
(54) Friction joining

(57) A method of joining a pair of members (4, 5) comprises causing relative movement between a consumable friction member (1) and the members (4, 5) to be joined, whereby material from the consumable member is laid down onto adjacent upper surfaces of the members to be joined so that the members are joined via the laid down material. The region (6) between the members to be joined presents a substantially flat surface to the consumable member.

A consumable member is also described comprising a relatively thin walled tube containing a powder material (Fig 6, not shown).

Fig. 2A.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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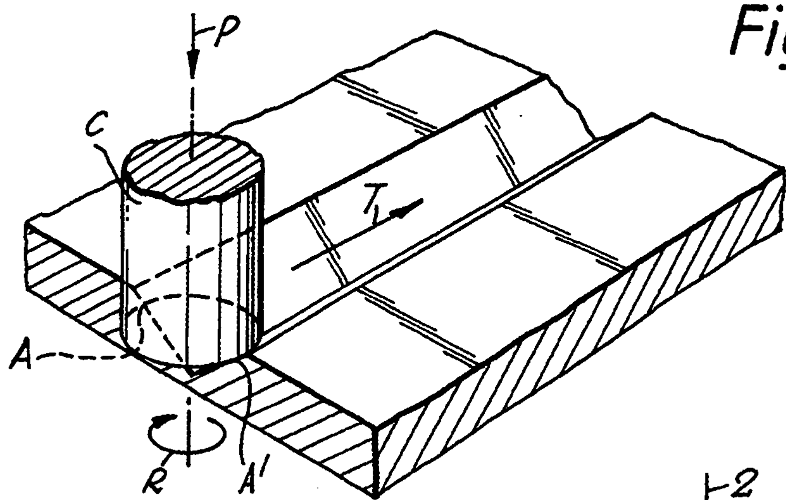


Fig. 1.

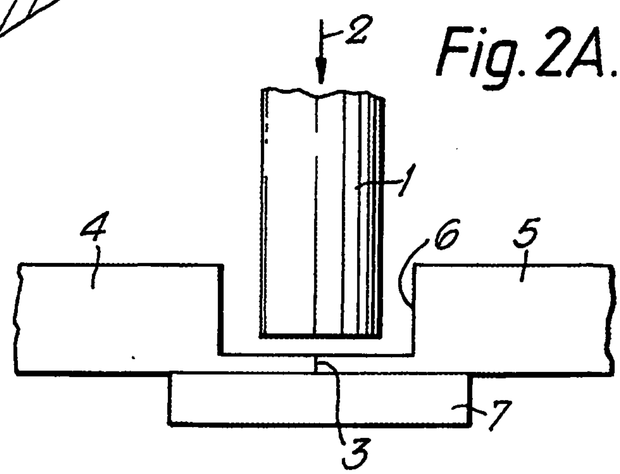


Fig. 2A.

Fig. 2B.

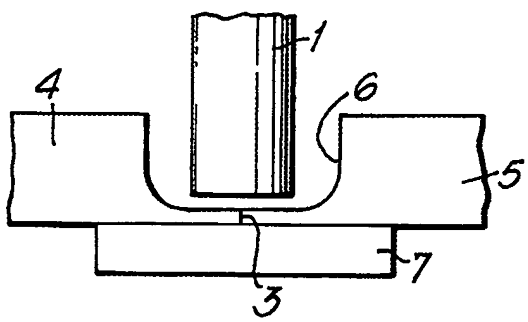


Fig. 3.

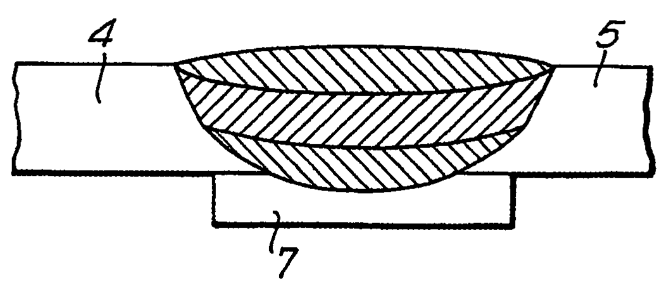


Fig. 4.

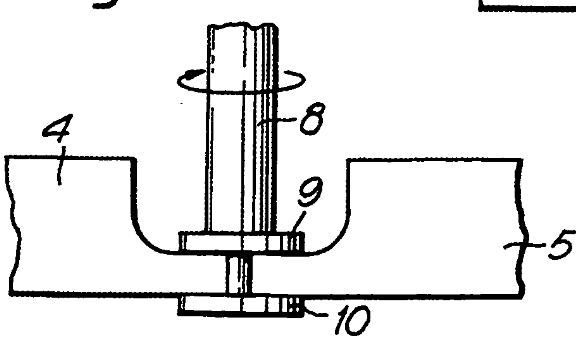


Fig.5A.

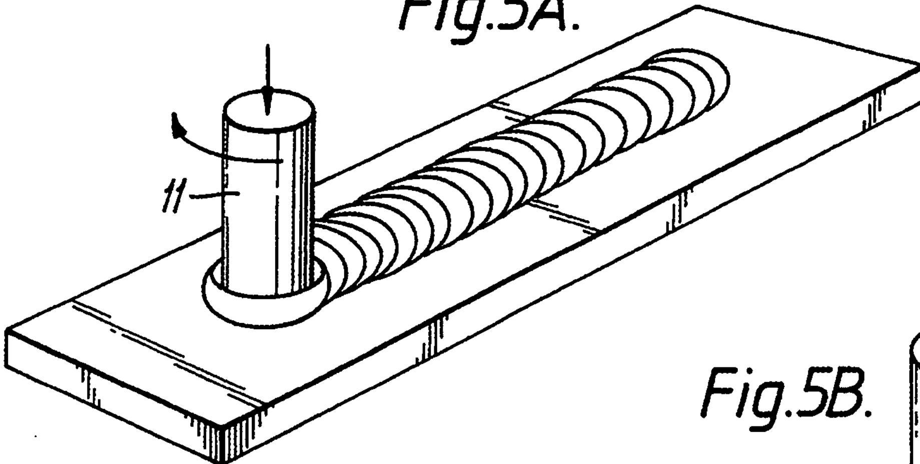


Fig.5B.

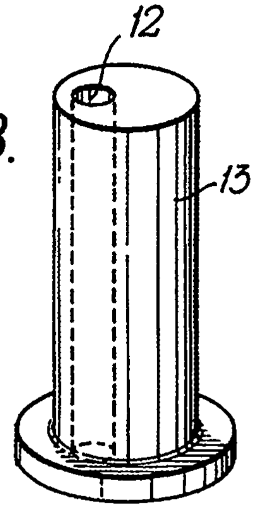


Fig.6.

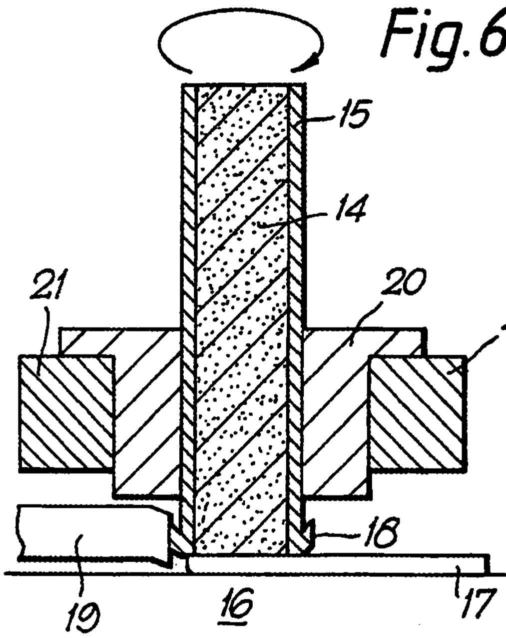


Fig.7.

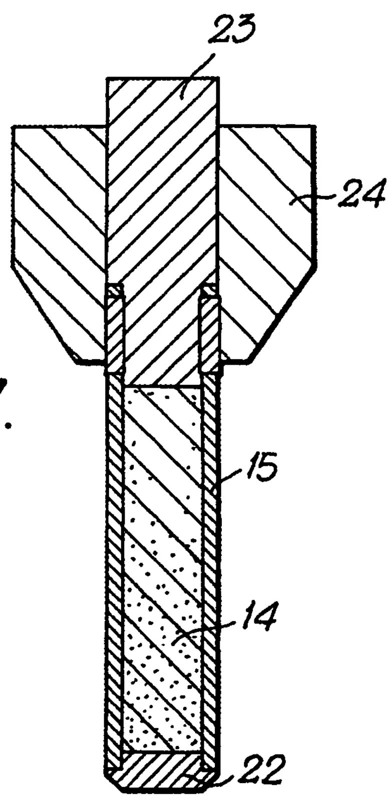


Fig.8(a)

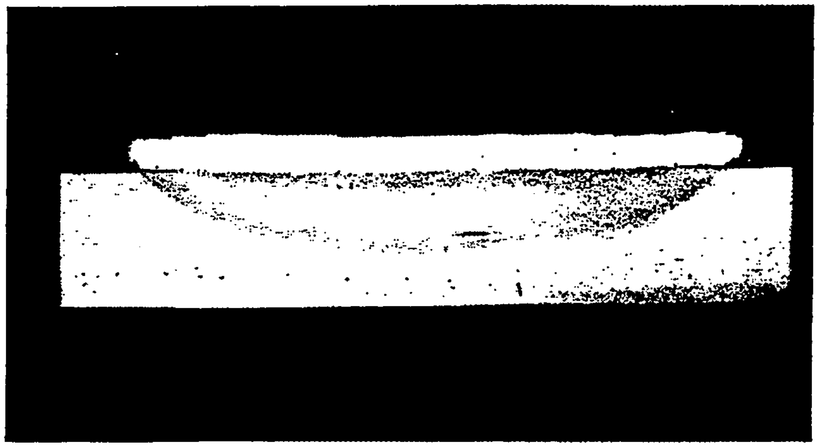


Fig.8(b)

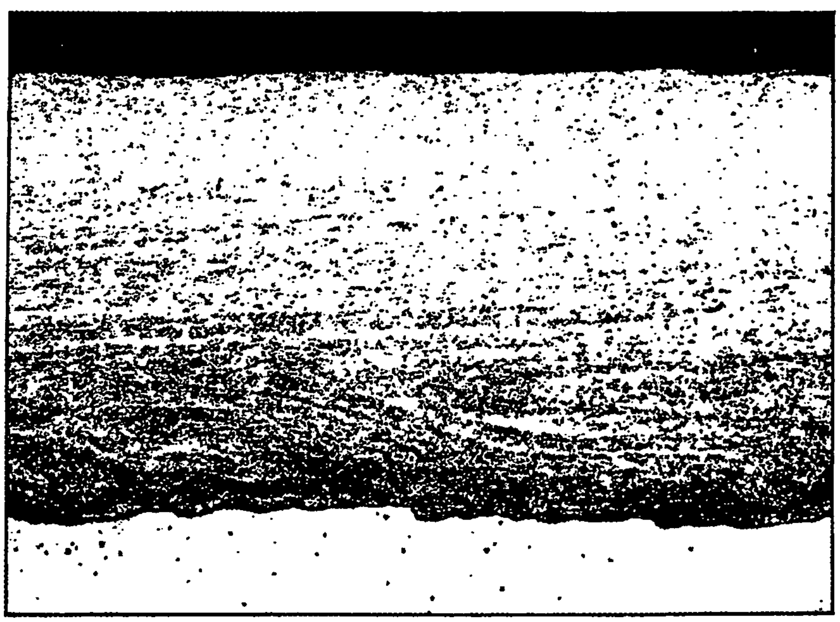
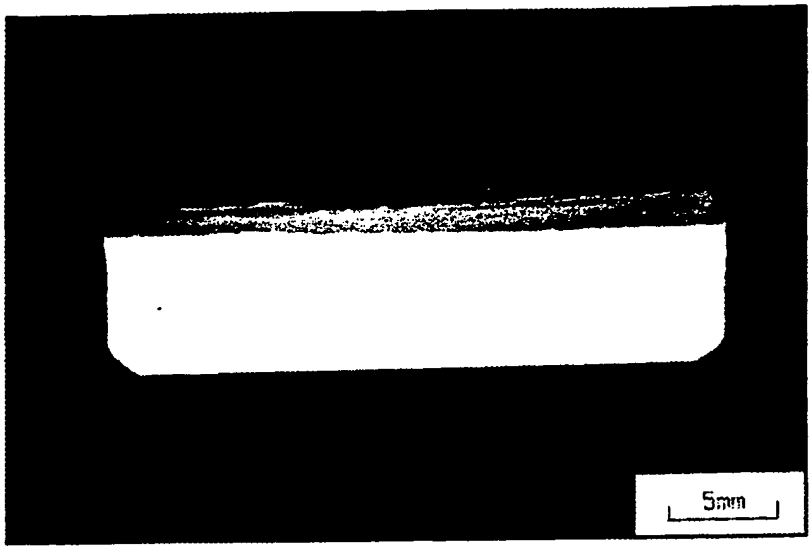
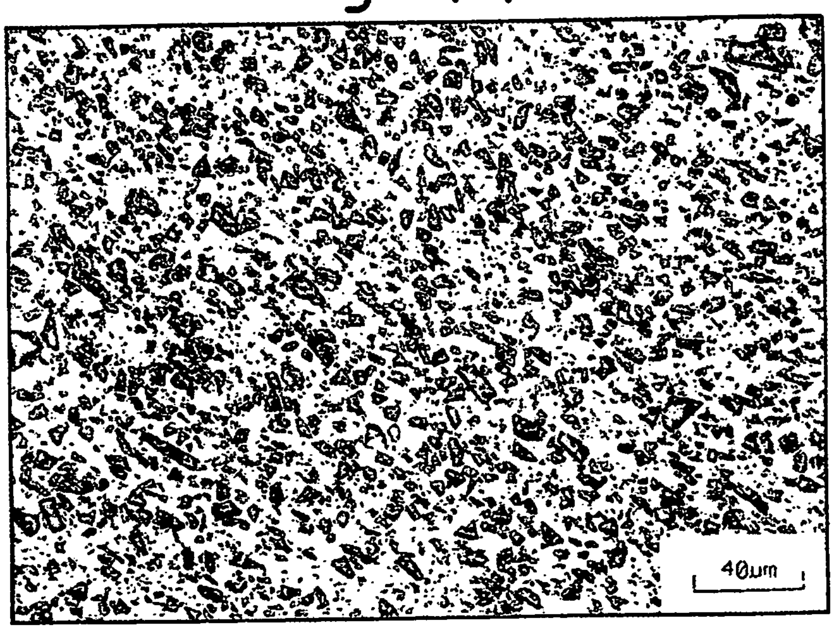


Fig. 9(a)



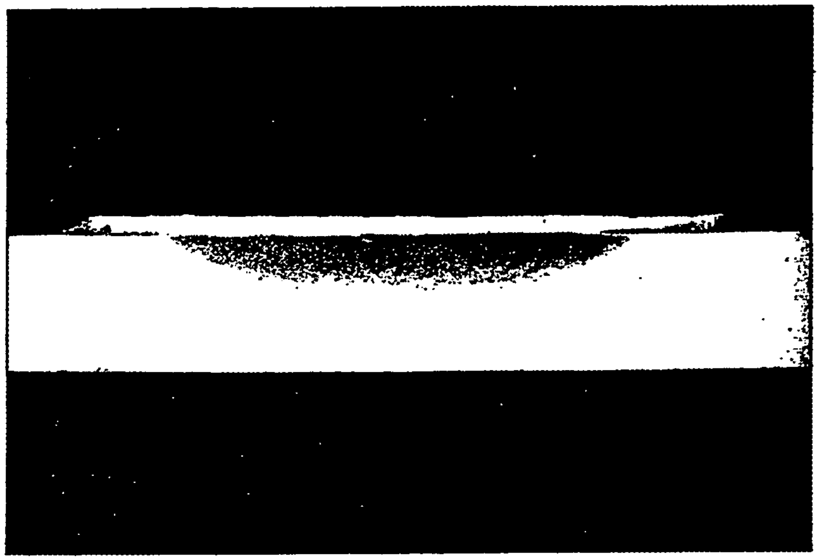
Macrograph showing a transverse section through a MMC deposit

Fig. 9(b)



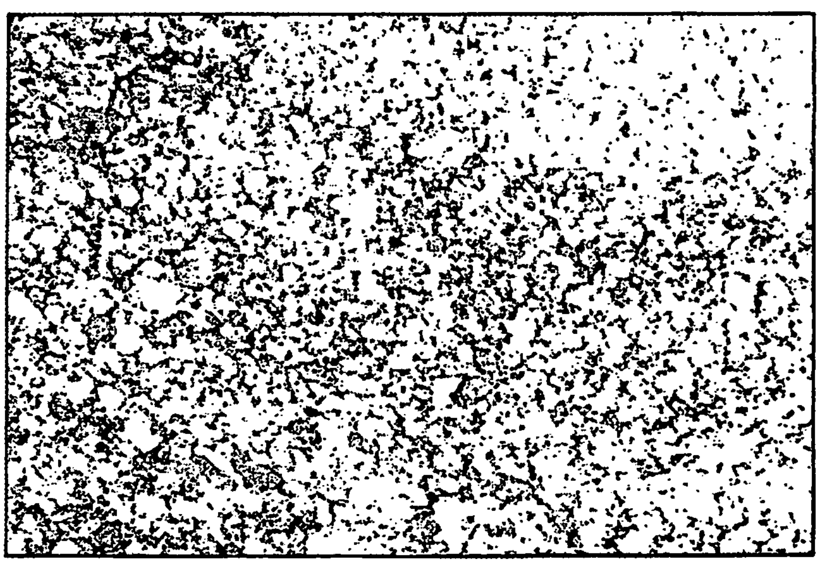
Micrograph showing the uniform dispersion of SiC in an aluminium alloy. The silicon carbide fraction is approximately 50 %

Fig. 10 DEPOSIT OBTAINED FROM AN Fe_3Al INTERMETALLIC POWDER CONSUMABLE ACCORDING TO FIGURES 6 AND 7



X4

a) Macrograph showing the deposit and part of the mild steel substrate



X500

b) Micrograph showing the fine grained nature of the deposit

Fig.11

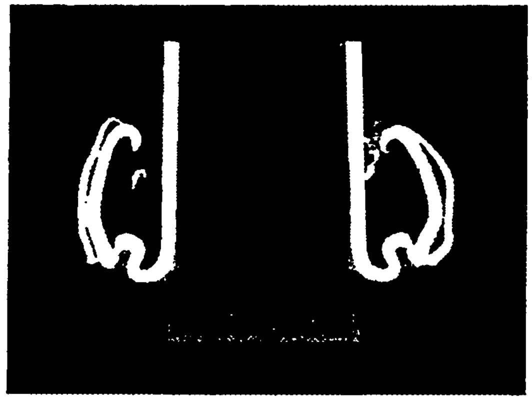
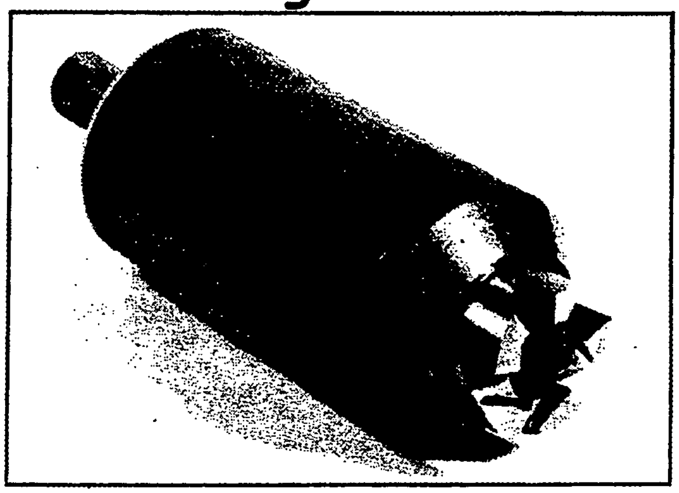
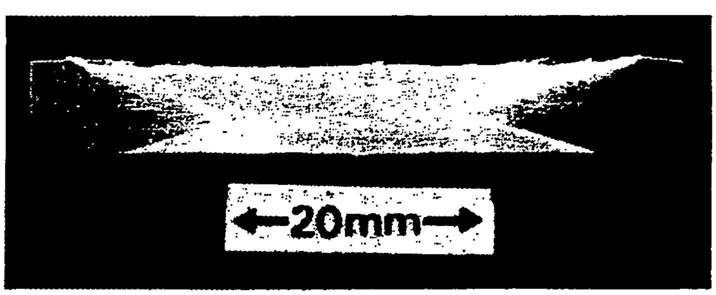


Fig.12



50 mm

Fig.13



Friction seam welding

IMPROVEMENTS RELATING TO FRICTION JOINING AND SURFACING

This invention relates to the joining and/or surfacing of materials. For example, joining of MMC type materials and/or surfacing with metallic powders and mixtures, including MMC type powders.

Friction joining of plates by a rotating consumable was first disclosed by Klopstock and Neelands in British Patent No. 572,789. However, the technique described has not been successful. An important reason for this has been the use of a V or U preparation which causes the generation of defects. Since then, there have been numerous developments in application to both joining and surfacing, including variation in motion of the consumable (such as oscillation and so called orbital motion), application of the friction process to dissimilar metallic materials, and to plastic materials, as well as to certain ceramics such as aluminum to alumina.

The friction process has also been used to extrude materials with a reduction in cross section, and to plug cavities with an increase in cross section, as disclosed in EP-A-0460900 and WO-A-93/04813.

According to one aspect of the present invention, a method of joining a pair of members comprises causing relative movement between a consumable member and the members to be joined, whereby material from the consumable member is laid down onto adjacent upper surfaces of the members to be joined so that the members are joined via the laid down material, and wherein the region between the members to be joined presents a substantially flat surface to the consumable member.

Thus, in this aspect of this invention, the friction process (with a rotational, orbital or reciprocating movement applied to the consumable member) is used to join the members by creating a butt weld in one or more passes. Furthermore, the use of a substantially flat surface overcomes the problems of the Klopstock technique outlined

above. In order to achieve a complete joint, the first pass may be an autogenous friction weld (friction stir welding) or a suitable groove may be machined in the opposite face, and this groove similarly filled by friction processing, alternatively, the base of the groove may be in the form of a backing bar, on which the deposit is laid down, with the backing bar subsequently being machined away.

Typically, the maximum transverse dimension (e.g. diameter) of the consumable is about 80% of the transverse (short) dimension of a groove containing the flat surface.

Preferably, the region between the members to be joined and the leading end of the consumable both present a substantially square profile. The region is normal to the axis of the consumable member.

As will be explained in more detail below, the geometries proposed by Klopstock are not ideal for joining members using this technique. However, the technique of the invention leads to very good joints.

In general, a shallow profile is preferred, particularly for the first or joining pass, with a significant thickness to the abutting edges.

The method can join one metal matrix composite (MMC) type material to another metallic material which may or may not be nominally the same as the matrix material of the MMC. At least one of the members to be joined may be an MMC although this is not essential.

MMC type materials differ from most metals and alloys in that they not only degrade or change in physical/ chemical constitution when heated to melting point, but segregation of the particulate can occur. Thus, whereas there are many welding techniques such as shielded arc welding, inert-gas welding, submerged arc welding and so forth, as well as non-arc methods such as electron beam and laser welding, these processes require melting of both the consumable and the parent material or materials, and are

therefore not well suited where one or more of these is an MMC type material.

Furthermore, the fusion techniques mentioned above have, when applied to metals, virtually completely superseded the Klopstock friction method for reasons of greater travel rate, greater penetration, greater joining rate for the full thickness and so forth. Thus, in practice, there is no advantage to the Klopstock method over arc or power beam processes for joining metals.

However, the friction process with a suitable consumable can be adapted successfully to join MMC type materials, or one MMC type material to another, particularly in the form of a butt joint between the materials concerned. For this, the corresponding edges of the materials to be joined are to present a suitable profile to the consumable member used to join the materials.

The friction process is used to join first the apex or central zone of the profile presented by the butt joint. In some cases in place of a consumable member, a rotating or oscillating probe can be used to effect an autogenous joint, as described in PCT Application No. PCT/GB 92/02203. Thereafter, according to the thickness of the materials to be joined, a number of friction surfacing passes are carried out to fill the joint profile.

Another problem which arises in the friction surfacing field is the need to provide surface deposits of powders or mixtures of powders and the like. It has previously been proposed to use a metallic consumable member containing an insert of a dissimilar material but this can lead to undesirable deposits.

In accordance with a second aspect of the present invention, a consumable member for use in a friction surfacing process comprises an outer tube containing particulate material to be deposited, the thickness of the tube being such that, in use, the tube forms substantially no part of the deposit. This aspect of the invention is

not only applicable to the joining of members as described herein, but more generally to the provision of a surface deposit on a substrate, particularly an MMC surface deposit. Typically, the thickness of the wall will not be less than 10% of the maximum transverse dimension of the consumable member. Preferably, the wall thickness is less than 15% of the maximum transverse dimension (diameter) of the consumable member.

Alternatively, a metal or alloy can be used in some circumstances for the consumable member used in the first aspect of the invention for joining to an MMC type parent material. It is preferable, however, to use an MMC type consumable, or alternatively a metallic material containing an insert of dissimilar material (which can comprise such a concentration of the MMC particulate or ceramic) or powder admixture to give rise to the deposit desired, including MMC type deposits. The deposit may nominally match one or other of the MMC type materials to be joined, or be of intermediate character, or of such a character as to impart particular properties to the joint. If appropriate, different consumables may be used at different stages in the surfacing or building up of the joint.

The second aspect of the invention can also be used to lay down a surface deposit without any joining function. In either case, to apply granular or powder material in the friction surfacing process, the material is contained in a suitable sleeve or can, by which the material can be given the desired motion to develop frictional heating at the overall applied load. The conditions of operation are so chosen that the can or sleeve forms only a minor part, or in the extreme, no part of the deposit itself, but is mainly utilised as a containment means up to the point of developing a plasticised layer comprising largely the granular or powder mixture. For an MMC type deposit a metal powder, which serves as a matrix for the MMC, may differ in composition from the metal or alloy of the sleeve. During operation, a flash is formed on the

consumable member which comprises the sleeve, (or can) material, with little or none of the powder MMC.

The contents of the tube may be a mixture of elemental or other powders, such that alloying or the formation of an intermetallic or an MMC type material occurs during the friction processing.

The friction techniques used for joining, and in particular for filling the joint by a surfacing deposition, may also be used to deposit material onto a suitable substrate or base of parent material. The parent may be a metal or alloy, or an MMC type material, and the consumable may be either an MMC type material, or a metal or alloy containing an insert of differing material (such as an MMC type or an equivalent powder mix), or be largely in powder form contained within a sleeve or can as described above, for deposition of pure metals, alloys, intermetallics or materials with fibres or whiskers for further strengthening where desired, and so forth. In a multi-pass joining or surfacing method different materials, alloys or powder compositions may be used.

Preferably, the method further comprises continuously removing any flash as the flash is formed.

These and other aspects of the invention will be apparent to those skilled in the art, from the following description and accompanying drawings and photographs, in which:-

Figure 1 shows an arrangement according to prior art;

Figures 2 A and B show two examples of arrangements according to the invention for joining by friction surfacing;

Figure 3 shows a further arrangement for joining according to the invention;

Figure 4 shows yet another arrangement for joining according to the invention;

Figures 5 A and B show two arrangements of consumable according to prior art in friction surfacing;

Figure 6 shows a modified consumable for deposition of powder by friction surfacing according to an example of the invention;

Figure 7 shows a further arrangement according to the invention for deposition of powder;

Figures 8 A and B show macro and microsections respectively of the deposition obtained from a metallic powder consumable according to Figures 6 and 7.

Figures 9 A and B show macro and microsections respectively of the deposition obtained from an MMC powder consumable according to Figures 6 and 7.

Figures 10a and 10b are a macro and microsection respectively of a deposit obtained from an Fe_3Al intermetallic consumable of the type shown in Figures 6 and 7;

Figure 11 illustrates the formation of the flash from a thin-walled container tube;

Figure 12 illustrates a tool for machining of the flash as it is being formed; and,

Figure 13 illustrates a weld made using the technique of Figure 2b.

In the British patent No 572 789, Klopstock and Neelands describe (Figure 1) a process akin to what is currently known as friction surfacing, in which commonly a member C which is rotating R is pressed against a substrate to heat the extremity of the rotating member by friction, and form a plasticised layer on its end. By traversing T the rotating member across the substrate (or vice versa), the plasticised layer becomes deposited on and bonded to the substrate, under suitable operating conditions of load, rotational speed and travel rate.

In the Klopstock and Neelands disclosure, although no operating values are quoted as an example, it is claimed that two plates, with a V preparation of total included angle of 90° or greater and extending to the full depth or thickness of the plates, are joined by a third member which is rotated and pressed against the V profile and traversed

along the joint line, Figure 1. Materials quoted include hard metals, alloys, steel, cast iron, brass and aluminium. For steel, the rotating member is of greater manganese and silicon content, together with side grooves or slots to provide for flux addition. The diameter of the rotating member is equal to or less than the opening to be filled, such that it contacts or presses against the sides of the V-preparation. The end of the member may be square or chamfered at an angle (more obtuse than that of the V-profile), such that it contacts the sides, for instance at points A-A'.

However, this arrangement presents difficulties in practice. In particular, the end of the rotating member only contacts the sides of the V-preparation during part of any one revolution, and is exposed to the atmosphere or environment during other parts. The use of a flux is thus necessary, and for some reactive materials such as titanium it is difficult to obtain sufficient protection from oxidation. Moreover, it is difficult to maintain a stable shape to the end of the rotating member. If it is initially square, it rapidly deforms and becomes partially chamfered. Alternatively, if the end is initially chamfered, contact at the sides again deforms the end profile. In addition, it is not possible to maintain a deep plasticised volume sufficient to fill the V-profile, and at the same time to maintain contact with the apex of the V, or to prevent deformation of the extremities of the V-preparation forming the apex in the parent plate. The disclosure according to Klopstock and Neelands will produce a joint with a lack-of-fusion defect extending along the base of the V-shaped preparation.

Thus, according to an aspect of the present invention, it is preferred to utilise a square or substantially square preparation in the joining of materials by a third member by means of a frictional process, as illustrated by the examples in Figures 2a and 2b. The consumable member 1 is for convenience rotated, but may alternatively be

oscillated to and fro, or given an orbital motion, as desired. The end of the member 1 being heated by friction under the applied load 2 becomes plasticised and, with traverse along the joint 3, the plasticised material is deposited in a manner similar to friction surfacing of a flat substrate. The profile of the groove 6 presented by the materials 4,5 to be joined may be a simple profile with substantially square sides, Figure 2A, or alternatively with corners of small radius or chamfered, Figure 2B. Preferably the consumable member 1 substantially fills the profile across the joint, and deposits a relatively thin layer of the order of 1mm thickness or greater. The member 1 is typically circular in cross-section and has a diameter substantially 80% of the width of the groove 6.

To fill a joint profile of yet greater depth, two or more passes are made at nominally the same operating conditions, until sufficient total thickness of deposit is obtained. A final pass with a consumable member of larger size or greater diameter can be used to complete the joint by depositing material on the surface of the two plates 4,5 to be joined as well as on the previously deposited material. Where desired, the deposited material can be machined to present a more smooth surface, and/or to establish the desired profile at the sides for the subsequent filling pass. For the final pass, the profile may be in the form of a segment of a circle of large radius. An example of a weld made by a technique based on Figure 2b is shown in Figure 13. The material is an aluminium copper magnesium alloy (7075), of thickness 6mm, and filled in a total of two passes. The reverse pass obscures the original butting edges of the two plates which were joined by friction surfacing, as described. The consumable used is a different aluminium alloy, in order to be distinguished from the materials being joined in this example.

One advantage of the generally square profile is that the rotating member contacts the plates 4,5 to be joined

not on an edge or corner but across the full face of the member, so that pressure is exerted on the plasticised layer across its width. Another advantage is that there is substantially no transverse or lateral force to be resisted, compared with the components of the applied load acting on a V-profile of the order of 90° or greater included angle, as in Klopstock and Neelands.

The butting edges of the two parts 4,5 to be joined may be as a simple butt, or may be partially scarfed. Alternatively, the opposing edges may be separated to allow plasticised material to flow into the gap, Figure 3. Preferably in all these examples of Figures 2 and 3 the back faces of the materials to be joined are supported on a suitable plate or anvil 7 to react the applied load. In the case of separated components, the supporting material 7 is preferably of higher melting point or strength or, for example, a ceramic, in order to reduce the tendency of the deposited first pass to bond to the support base. In some cases, it is necessary to cut off the support material, and/or machine a suitable preparation on the reverse side which is then filled by friction surfacing, as described, to complete the joint. In Figure 3, the plate 7 is shown slightly dished but is effectively substantially flat. In other cases, the plate 7 would be exactly planar.

In an alternative arrangement, the butting faces of the two components 4,5 to be joined are first joined by the method described in our patent application No. PCT/GB 92/02203 using a non-consumable rotating probe 8 which extends through the butting faces, with shaping or forming cheeks 9,10 on the two surfaces (upper and lower) of the butted edges Figure 4. Alternatively, the probe may only extend partially through the butting material, with a shaping cheek on one side only. In either case, the remainder of the nominally rectangular joint profile is filled thereafter, as described above, with one or more surfacing passes to consolidate the joint.

Commonly, for friction surfacing such as in applying a hard facing to a softer substrate, and for friction joining, the consumable member 11 normally comprises a solid bar of the desired hard facing material; see Figure 5A. Alternatively, and especially for MMC type materials, the desired consumable material may not be readily available as a solid bar. Here the desired constituents for the deposit may be incorporated into a suitable bar, for example as a solid or in the form of granules or even a powder inserted into a cylindrical hole 12 in the bar 13, and the whole used to form a deposit by the friction surfacing process, Figure 6B. However, the range of materials that can be produced in this manner is limited to the volume fraction of the additional insert in the total section of the supporting matrix of the consumable member.

According to a further aspect of the invention, a surfacing deposit is obtained from a powder which may be a pure metal, an alloy, a mixture of metals or alloys, an intermetallic, or an MMC type material containing particulates such as ceramics, with little or no contribution from the material of the supporting structure of the consumable member.

The intense plastic deformation occurring in friction processes allows alloys to be made, during the processing, from elemental or other powders. This approach presents an alternative method for fabricating some complex materials, e.g. intermetallics.

In one method, according to this further aspect, the desired material as a powder 14 is packed into a relatively thin-walled tube 15, and the whole is rotated and pressed against a substrate 16 to develop frictional heating, Figure 6, as in conventional friction surfacing, and generate a deposit 17. There are, however, significant differences in the detail of the process characteristics, the most apparent being that the tube material takes only a minor, and possibly even no part in the plasticised material being deposited. Instead, the tube wall 15 forms

largely as the flash 18, and is rolled back as the consumable member 15 advances in frictional contact with the substrate 16. The tube wall therefore serves not only to contain the powder 14, but also to impart relative motion under applied load, while protecting to a significant degree the heated powder from external contamination or oxidation. Moreover, this arrangement gives rise to relatively limited axial heat conducting through the powder compared with the heat conduction along the tube. The softening of the latter promotes the preferential formation of the flash 18 comprising largely the wall material, with relatively insignificant amounts of the powder material. Conveniently, the deforming tube wall may be machined off by a suitable cutting tool 19 as it is being formed. As the tube containing the powder is mechanically less resistant to bending under the applied axial load compared with a solid bar, it is preferable to support the tube close to its operating extremity. This may be in the form of a bush 20 through which the rotating tube passes, supported by bearings 21.

To initiate the process, in one example, the extremity of the powder-filled tube 15 is closed with a plug 22 of suitable material, Figure 7. This may be a metal to provide a solid end, as in conventional friction surfacing. Alternatively, the plug 22 may be formed from material similar to the powder material, in order to avoid the start of the surfacing deposit being substantially different in form or composition from the remainder. The powder for the plug may be first consolidated by hot isostatic pressing or by other means, or alternatively formed from previously deposited layers of friction surfaced material. The powder-filled tube 15 may conveniently be joined to a solid mandrel 23 and held in a suitable chuck or collet 24 for rotation.

An example of metal deposition from a powder-filled tube by friction surfacing is shown in Figure 8 for an austenitic stainless steel powder. The substrate is a

carbon manganese steel, nominally 6mm thick, and the consumable nominally 25mm diameter and wall thickness 1.6mm in stainless steel. With a traverse rate of 4mm/sec and rotational speed 690rpm, a deposit was obtained of approximately 27mm width and 1.5mm thickness, adhering firmly to the mild steel substrate, Figure 8A, except at the extreme edges of the deposit (as is common in friction surfacing). The detailed microsection, Figure 8B, shows the powder to be well consolidated, with substantially no porosity, and well bonded with no cracks or similar discontinuities between the deposit and the substrate. Some mechanical working of the substrate is apparent, as well as the bonding with the powder.

As an example of friction surfacing from an MMC type powder, a mixture of aluminium alloy and silicon carbide such that they comprise approximately equal volume fractions was packed into an aluminium alloy tube of external diameter 25mm and wall thickness 3.2mm. This was rotated at 690rpm and pressed against a flat aluminium alloy substrate of thickness 6mm, and traversed along the substrate at 4mm/sec. This gives rise to a nominally homogeneous MMC deposit of silicon carbide in the alloy, approximately 25mm in width and 1 mm in thickness, Figure 9A. It is noted that, although the relative cross-section of powder to the containment tube is approximately 55%, the deposit apparently contains virtually none of the containment tube material. The microsection of the deposit, Figure 9B, shows a substantially uniform distribution of the silicon carbide particulate in the aluminium alloy matrix. The particulate is generally below 5μ in size.

The deposit is characterised by a high proportion of silicon carbide in an aluminium alloy, which is beneficial in imparting wear resistance and improved strength at elevated temperatures. The proportion of additive may be as low as 1% or less, or alternatively in excess of the

order of 40% with respect to the total metallic powder content.

An example of a deposit produced from an intermetallic powder contained in a tube is shown in Figures 10a and 10b. The substrate is a mild steel, nominally 6mm thick, and the containment tube nominally 19mm diameter and wall thickness 2mm, also in mild steel. With a traverse rate of 2mm/sec and rotational speed 832 rpm, a deposit was obtained approximately 30mm width and 1mm thickness. The deposit was uniformly fine-grained, which is desirable for intermetallics, in order to improve upon their poor ductility.

Under suitable operating conditions, the wall of the powder-filled tube is not broken up, nor does it form part of the deposit. Typically, the wall is deformed and turned back upon itself as, illustrated in Figure 11. The shape varies in detail, due to a combination of restraints provided by the support bearing or bush, the deposit and substrate, with respect to the malleability of the tube material and its wall thickness. Preferably, the flash formed by the deforming tube wall is continuously removed as it is being formed. A suitable tool is shown in detail in Figure 12, which also acts as a support bearing to the powder-filled tube. The cutting tool for the flash may also be adapted for machining the deposit. In either case, the tool is rotated at a speed different from that of the tube, or even in the opposite sense, to obtain suitable cutting speeds.

CLAIMS

1. A method of joining a pair of members, the method comprising causing relative movement between a consumable member and the members to be joined, whereby material from the consumable member is laid down onto adjacent upper surfaces of the members to be joined so that the members are joined via the laid down material, and wherein the region between the members to be joined presents a substantially flat surface to the consumable member.

2. A method according to claim 1, wherein the join between the members is formed in a groove with a substantially flat base.

3. A method according to claim 2, wherein the maximum transverse dimension of the consumable member is about 80% of the transverse dimension of the groove.

4. A method according to any of the preceding claims, wherein at least one of the members is a metal matrix composite.

5. A method according to any of the preceding claims, wherein the consumable member comprises a metal or alloy.

6. A method according to any of claims 1 to 5, wherein the consumable member comprises a granular or powder material.

7. A method according to claim 6, wherein the granular or powder material is a metal matrix composite, or forms a metal matrix composite deposit during the friction surfacing process.

8. A method according to any of the preceding claims, wherein facing surfaces of the members to be joined are spaced apart, a backing member being provided extending across the join region.

9. A method according to claim 8, wherein the backing member is removed following the joining process.

10. A method according to any of claims 1 to 8, wherein the members are initially joined by forming an autogenous

joint by means of a rotating or oscillating non-consumable probe.

11. A method of joining a pair of members substantially as hereinbefore described with reference to any of the examples shown in Figures 2 to 4 of the accompanying drawings.

12. A consumable member for use in a friction surfacing process, the member comprising an outer tube containing particulate material to be deposited, the thickness of the tube being such that, in use, the tube forms substantially no part of the deposit.

13. A member according to claim 12, wherein the thickness of the tube wall is not less than 10% of the maximum transverse dimension of the consumable member.

14. A member according to claim 12 or claim 13, wherein the consumable member has circular cross-section.

15. A consumable member according to any of claims 12 to 14, wherein the particulate material is chosen from pure metal, an alloy, mixtures of metals or alloys, an intermetallic, or an MMC type of material.

16. A consumable member substantially as hereinbefore described with reference to any of the examples shown in Figures 6 and 7 of the accompanying drawings.

17. A method of joining a pair of members according to any of claims 1 to 11, wherein the consumable member is constructed in accordance with any of claims 12 to 16.

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Examiner's report to the Comptroller under Section 17
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Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Documents considered relevant following a search in respect of Claims :-
1-11,17

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

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&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2222378	(FRICTEC)	1,5,7
X	GB 1472002	(ROCKWELL)	1,2,5,8

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